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ABSTRACT

This report is essentially a collection of information gathered from a broad cross-section of the building community that provides a description of the state of affairs existing mid-1974 through mid-1975 in the private sector of the building community with regard to solar heating and cooling of buildings. The report additionally contains information about the needs perceived by the private sector with regard to governmental actions beyond research required to induce widespread application of solar energy for the heating and cooling of buildings. Following the first section that outlines the background and purpose of the report and the conduct of the study, the remainder of the report is divided into two sections: (1) Activities of the Building Community describes selected interests and projects of individuals and organizations; and (2) Expressed Needs and Concerns of the Building Community describes the nonproprietary technical information needs and the societal/institutional, building design/construction, and product design/manufacture concerns voiced by the private sector of the building community. (Author/MLF)

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Solar Heating and Cooling of Buildings:

Activities of the Private Sector of the Building Community and its Perceived Needs Relative to Increased Activity

Building Research Advisory Board

Commission on Sociotechnical Systems

EA 010 068

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SOLAR HEATING AND COOLING OF BUILDINGS:
ACTIVITIES OF THE PRIVATE SECTOR OF THE BUILDING COMMUNITY
AND ITS PERCEIVED NEEDS RELATIVE TO INCREASED ACTIVITY

Prepared by the
Committee on Solar Energy in the Heating and Cooling of Buildings
Building Research Advisory Board
Commission on Sociotechnical Systems
National Research Council

National Academy of Sciences
Washington, D.C.
1976

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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FOREWORD

The growing disparity between our nation's demand for energy and the supply of nonrenewable fuels is a generally accepted fact. The significant proportion of this demand directly attributable to buildings is another generally accepted fact. Given these facts, there is a clear need to approach all building construction and remodeling activities with the unwavering goal of conserving energy and maximizing the use of renewable sources of energy such as the sun. To this end, several federal agencies are undertaking and supporting programs and activities that will help make solar energy technology a viable alternative method for heating and cooling buildings, and the Building Research Advisory Board is privileged to be participating in these efforts.

The Board gratefully acknowledges the work of the Committee on Solar Energy in the Heating and Cooling of Buildings responsible for compiling this report and sincerely appreciates the contributions made to that effort by the individuals who participated in the December 1974 workshop in Tempe, Arizona, and by those who responded to the mail survey conducted after that workshop.

CHARLES E. SCHAFFNER, Chairman
Building Research Advisory Board

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I

INTRODUCTION

A. BACKGROUND

As part of its Research Applied to National Needs (RANN) program, the National Science Foundation (NSF) initiated, in fiscal year 1971, a program focusing on the application of solar energy in the heating and cooling of buildings. The plan for this activity called for the support of research and development aimed at testing and proving new concepts, and its ultimate goal was to complete and disseminate the results of proof-of-concept demonstration projects.

When the NSF initiated this program, certain segments of the private sector of the building community already had begun or were continuing independently to develop the technology needed to harness solar energy for heating and cooling buildings. By the end of fiscal year 1973, participation by the building community in the RANN program was increasing, but evidence indicated that independent building community efforts also were increasing in number and scope. Thus, in the early part of fiscal year 1974 the NSF requested that the National Academy of Sciences (NAS), through its Building Research Advisory Board (BRAB), assist it in effecting a linkage between the RANN program and the independent efforts of the private sector of the building community. Specifically, the request was to:

1. Identify solar energy research, development, and applications programs being undertaken by the private sector and the nonproprietary research needs of the private sector that should be considered for inclusion in the RANN program.

2. Recommend a cost-effective information dissemination system for communicating the results of RANN-supported solar energy research to those in the best position to use it.

3. Bring up to date the 1963 publication of the Building Research Institute, Solar Effects on Building Design.

In response to this request, the NAS entered into a contract with the NSF to execute these tasks. A BRAB project committee--the Committee on Solar Energy in the Heating and Cooling of Buildings--was appointed for this purpose and began its work.

In the early part of fiscal year 1975, the NSF requested that an additional task be undertaken by the Committee, that of characterizing the segments of

the building community involved in solar energy projects. Following the creation of the Energy Research and Development Administration (ERDA) in the latter part of fiscal year 1975 and the transferrence to ERDA of portions of the RANN solar energy activities, responsibility for administering the contract between the NAS and the NSF was transferred to ERDA and the NAS entered into an additional contract with ERDA to enable the BRAB Committee to undertake this characterization.

B. PURPOSE OF THE REPORT

This report was prepared by the Committee in response to that portion of the contract relating to identification of ongoing or newly undertaken activities and complementary research needs of the private sector. Two other Committee reports, Solar Heating and Cooling of Buildings: An Information Dissemination Process and Solar Heating and Cooling of Buildings: Solar Effects on Building Design, respond to the other tasks posed by the NSF and ERDA contracts.[1]

This report is essentially a collection of information gathered during a relatively short period of time (mid-1974 through mid-1975) from a broad cross-section of the building community; it is not encyclopedic, but it does provide a description of the state of affairs then existing in the private sector of the building community with regard to solar heating and cooling of buildings. The report additionally contains information about the needs perceived by the private sector with regard to governmental actions besides research required to induce widespread application of solar energy for the heating and cooling of buildings. It must be noted that the mention in this report of any particular project, organization, person, product, system, or material does not constitute or imply any endorsement by the Committee or the National Academy of Sciences-National Academy of Engineering-National Research Council and that no attempt has been made to evaluate the data submitted. In addition, while the intent of the project has been to report on nonfederally supported activities, a number of persons, companies, and organizations identified in this report are engaged in both federally supported and independently supported activities and are noted in order to provide broader coverage.

C. CONDUCT OF THE STUDY

To identify solar energy research, development, and applications programs being undertaken by the private sector, numerous trade and professional societies and associations representing the various segments of the building community were requested in early 1974 to ask their memberships to identify those conducting such programs. Approximately 200 individuals and

[1]Early in the project, an interim report of the Committee entitled Solar Heating/Cooling of Buildings: Current Building Community Projects and containing synoptic profiles characterizing ongoing activities was transmitted to the NSF; subsequent to the issuance of this document, the technical representative of the NSF requested that efforts to produce reports containing individual in-depth profiles of these activities be terminated.

organizations were identified by this process, and they subsequently were contacted during the summer of 1974 in an effort to obtain detailed information on the level of their interests and the scope and status of their activities relating to solar heating and cooling of buildings.

Based on this information, as well as other data obtained at NSF workshops held during late 1973 and early 1974 and from the sales literature of manufacturers, symposia and continuing education program announcements, and other miscellaneous correspondence, individuals then involved in nonfederally supported solar heating and cooling activities and a few involved in federally supported activities were invited to a special workshop on December 9, 1974, in Tempe, Arizona, to discuss the status of their activities and their views on complementary research needs and other actions required to stimulate widespread application of solar energy for the heating and cooling of buildings. (A list of workshop participants is presented as appendix A.)

Subsequently, in lieu of convening a second workshop as had originally been planned, two questionnaires were devised--one to be sent to product manufacturers and one to be sent to members of all other building community segments--to elicit the same kind of information from a larger sample of those involved in nonfederally supported solar heating and cooling activities than could be done within a workshop format. A total of 1563 questionnaires were mailed and 323 responses were received, 43 of which were from product manufacturers. (See appendix B for copies of the questionnaires and a tabulation of responses.)

D. ORGANIZATION OF THE REPORT

The remainder of this report is divided into two sections: Activities of the Building Community, in which selected interests and projects of individuals and organizations are described; and Expressed Needs and Concerns of the Building Community, in which are described the nonproprietary technical information needs and the societal/institutional, building design/construction, and product design/manufacture concerns voiced by the private sector of the building community.

II

ACTIVITIES OF THE BUILDING COMMUNITY

Presented below are descriptions of activities related to the research, development, and application of solar energy for heating and cooling buildings being carried out in 1974-1975 by selected individuals and organizations. The activities described were identified by participants in the December 1974 workshop and by other individuals contacted to ascertain the extent of their interest in solar energy activities. The descriptions are intended only to indicate some of the kinds of projects and studies then under way and are not necessarily representative of all activities or of either the most sophisticated or the most interesting.

A. COMMERCIAL BUILDINGS AND OTHER LARGE FACILITIES

Bridgers and Paxton, Mechanical Engineering Consultants, was engaged in the design of solar heating and cooling systems for several commercial and institutional buildings. Two of the firm's larger projects are described below:

1. The Denver Community College building, a 278,000-square-foot facility located north of the city, was designed by the A-B-R Partnership of Denver and was to feature 50,000 square feet of roof-mounted water/glycol-cooled solar collectors, three underground storage tanks with a total capacity of 400,000 gallons, heat pumps to supplement the system, and other energy-conserving features (e.g., redistribution of people- and lighting-generated heat, heat extraction from exhaust fans, a solar-energy-heated hot water supply, double-glazed windows, and extra building insulation). The solar system was expected to cost 8.78 percent or $736,780 more than a conventional system; however, a 21 percent fossil fuel saving was anticipated. The return on the system investment was estimated at less than 11 years and by 1990 fuel saving was expected to amount to $90,000 per year.

2. The New Mexico State University Department of Agriculture building, 19,000-square-foot building to house offices and laboratories, had been designed for energy conservation and solar-powered heating and cooling. Estimated to cost $1.5 million, the building would feature 7,000 square feet of roof-mounted, water/glycol-cooled collectors to provide 80 percent of heating and cooling requirements, two 30,000-gallon underground tanks to store enough energy for a 3-day period, and an Arkla absorption chiller for cooling.

For further information, contact Frank H. Bridgers, Bridgers and Paxton, 213 Truman Street, N.E., Albuquerque, New Mexico 87108, 505/265-8577.

The Oliver Tyrone Corporation was involved in a three-phase experimental program to develop a design for an energy-saving solar-powered high-rise office building (Figure 1). Phase I required the building of a 20-square-foot, 1-1/2-story mock-up to be used as a learning model (cost--$30,000). During Phase II, a 30-square-foot, 2-1/2-story demonstration building was to be erected (cost--$90,000). Phase III would involve construction of a 6- to 10-story building designed to minimize heating and air-conditioning needs. Double-glazed clear-glass-covered collector cells made of coated aluminum plates with integrated fluid-carrying channels were to be used to gather solar energy striking the building facade and roof. Other participants included PPG Industries, Inc., the Aluminum Company of America, Standard Oil Company of Ohio, and Phelps Dodge. For further information, contact Donald W. Pulver, Executive Vice President, Oliver Tyrone Corporation, 1 Oliver Plaza, Pittsburgh, Pennsylvania 15222, 412/281-7400.

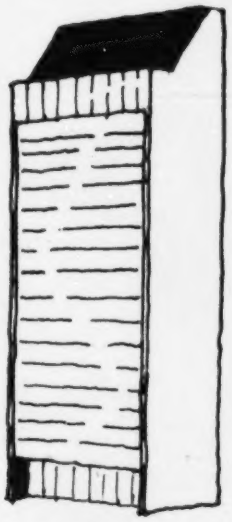

FIGURE 1 Oliver Tyrone Corporation's Conception of an Energy-Saving High-Rise Office Building.

R. A. Bell of the Massachusetts Institute of Technology was conducting a study to assess the feasibility of using solar energy to heat and partially cool the proposed 80- to 90-story Citicorp headquarters building. The possibilities of mounting solar collectors on the upper 40 stories and of using solar-powered dehumidification to provide up to 30 percent of the total load was being considered. Other participants included Consolidated Edison Company and Cushman and Wakefield. For further information, contact R. A. Bell, Massachusetts Institute of Technology, Energy Laboratory, Cambridge, Massachusetts 02139, 617/253-1000.

The Science Museum of Virginia was having its Physical Sciences Center designed to use solar heating and cooling. The 55,600-square-foot multilevel building for laboratories, shops, offices, a planetarium, and an auditorium was to

feature an extremely large (112 feet by 240 feet) sloping (30 degree) roof that would be covered with water/glycol-cooled flat-plate collectors. Three 50,000-gallon below-grade storage tanks--one each for high-temperature, low-temperature, and chilled fluids--also were to be used. An absorption unit powered by solar collectors or stored chilled water was to supplement primary cooling provided by a conventional 150-ton air conditioner. The building also was being designed to incorporate other energy-conserving features including extensive waste heat recovery, variable volume ventilation, and recirculation of filtered and heated air to reduce fresh air needs. Recovered energy was expected to supply about 50 percent of the heating and 40 percent of the cooling requirements. Completion of the building was anticipated in the fall of 1976. Other participants included Richard P. Hankins, Hankins & Anderson, Inc., Consulting Engineers, Richmond, Virginia; and James M. Glove, Glove, Newman, Anderson & Associates, Inc., Architects and Engineers, Richmond, Virginia. For further information, contact Edward C. Fordyce, Science Museum of Virginia, 217 Governor Street, Richmond, Virginia 23219, 807/770-4133.

Arthur Cotton Moore, Architect, planned to use solar energy to heat and cool the 7,000-square-foot Madeira School science building in McLean, Virginia (Figure 2). Of the estimated building cost of $400,000, approximately $30,000 was for the solar collector system, which included 4,500 square feet of roof-mounted flat-plate water/glycol-cooled solar collectors and a 10,000-gallon insulated storage tank. An oil-fired boiler would provide supplementary heating. Other participants included Flock & Kurtz, Engineers, Washington, D.C. For further information, contact Arthur Cotton Moore, Architect, 1214 28th Street, N.W., Washington, D.C. 20007, 202/337-9083.

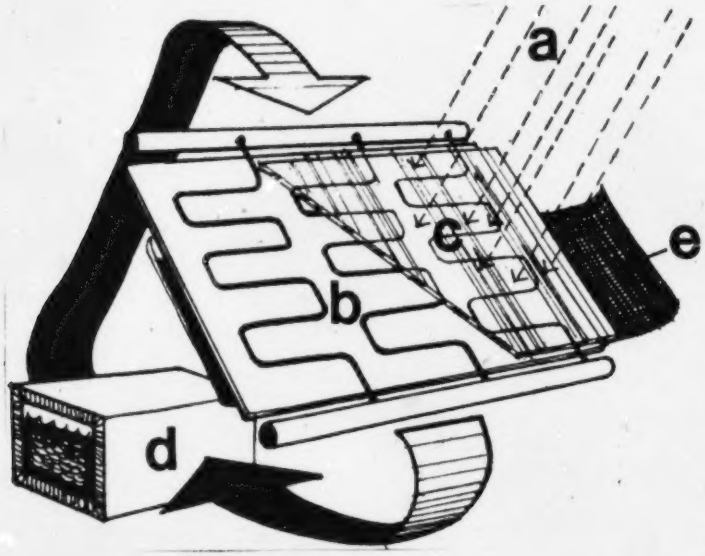

FIGURE 2 Schematic of the Madeira School solar system: (a) sun rays, (b) water coils, (c) glass cover, (d) storage tank, (e) conventional roof.

Syska and Hennessy's preliminary plans for the 1.2-million-square-foot Rockefeller Center Conference Center called for solar collectors to be utilized for heating and, possibly, for cooling. Also being considered was a heat recovery system for collecting, storing, and reusing excess energy from surplus interior heat. To provide partial heating for the Center, which was to be built on the 12th floor of the existing RCA Building in downtown New York City, 3,500 square feet of water/glycol-cooled flat-plate collectors were to be mounted on the roof of the Center. The system also would include 7,000-gallon storage tanks and was estimated to cost $150,000 more than a conventional system. Other participants included Ford & Earl Design Associates, Architects, New York, New York. For further information, contact Jagdish Prasad, Syska and Hennessy, Inc., 110 West 50th Street, New York, New York 10020, 212/489-9200.

The New York City Cary Arboretum was planning a 2-story, 35,000-square-foot building to use solar energy for heating, cooling, and hot water heating as well as other unique technologies for conserving energy and recycling wastes. Heat would be supplied by 6,000 square feet of roof-mounted flat-plate glycol-cooled solar collectors; compartmented storage tanks and supplementary heat pumps also were planned. Other energy-conserving design features were to include a greenhouse that would provide plant-generated oxygen and humidity for distribution into the building, a sod-covered roof, earth-banked walls, northwind-sheltering trees, thick masonry walls, double-glazed windows with shutters for use at night to reduce heat loss, extra large windows on the south and east walls to admit sunlight and heat, rainwater collection, and task lighting. This combination of systems was expected to decrease total energy consumption by 35 percent, utility energy consumption by 75 percent, and water consumption by 35 percent. Participants included Malcolm B. Wells, Architect, Cherry Hill, New Jersey, and Fred Dubin, Dubin-Mindell-Bloom Associates, Consulting Engineers, New York, New York. For further information, contact Thomas S. Elias, Cary Arboretum, New York Botanical Garden, Bronx, New York 10453, 212/933-9400.

Harrison, Beckhart and Mill, Architects, were planning a 300,000-square-foot office/condominium building as the first unit of a three-unit 770,000-square-foot complex. Solar-energy collectors, to be used for daytime absorption of solar energy for heating and nighttime radiant loss of heat for cooling, were to be mounted on the vertical exterior building walls and "heat pipes" were to be used to transfer heat energy from warmer areas of the building to cooler areas as needed. Fur further information, contact D. D. Beckhart, Harrison, Beckhart and Mill, Architects, 844 West Colorado Boulevard, Los Angeles, California 90041, 213/254-7141.

Jack Miller and Associates planned to use solar-energy collectors to heat and cool a new 6,374-square-foot laboratory facility for the University of Nevada. Energy was to be gathered by 6,000 square feet of roof-mounted flat-plate solar collectors for storage in two 10,000-gallon tanks. An electric immersion heater was to provide back-up heat, cooling was to be achieved with solar-powered absorption chillers, and several energy-saving design techniques were to be employed. Funding for the $648,000 project was being provided by the Desert Research Institute, the Fleishmann Foundation, and Mrs. Sulo Maki. For further information, contact Robert Fielden, Architect, Jack Miller and Associates, 522 East Twain Avenue, Las Vegas, Nevada 89109, 702/735-5222.

The Research and Design Institute was restoring a 125-year-old river mill in Providence, Rhode Island, to demonstrate the benefits of natural energy use. Solar, wind, and water power were to be used to supply building needs without disruption of aesthetic and cultural surroundings. Roof-mounted solar collectors were to supply heated water to a reservoir for distribution by utility-powered electric heat pumps while photovoltaic collectors and wind- and water-powered generators were to supply direct current for the lighting system. Alternate reserve systems were to be included and studies to determine human reactions to the environment were planned. Other participants included Brown University faculty and students. For further information, contact Ronald Beckman, Research and Design Institute, P.O. Box 307, Providence, Rhode Island 02901, 401/861-5390.

B. RESIDENTIAL PROJECTS

Barkmann Engineering's activities included the design and construction of several Santa Fe, New Mexico, residential projects that utilized several types of air collector and underfloor rock system both to store thermal energy and to provide radiant heat. In residential projects, the firm's design approach made use of air systems because their low-temperature output was compatible with space heating requirements, their cost was low, and their reliability was deemed high. The firm was exploring the use of passive low-cost solar energy in building design and the use of a wet-collector solar heating and cooling system for a bank. For further information, contact Herman Barkmann, President, Barkmann Engineering, 107 Cienega Street, Santa Fe, New Mexico, 505/982-8907.

Phoenix of Colorado Springs, a nonprofit corporation jointly sponsored by the local chapters of the National Society of Professional Engineers, American Institute of Architects, and National Association of Home Builders and local banks, developed a solar heated and cooled house (Figure 3) with 2,200 square feet of finished floor space at a cost of $91,000, of which $12,000 could be attributed to the solar system. The solar heating and cooling

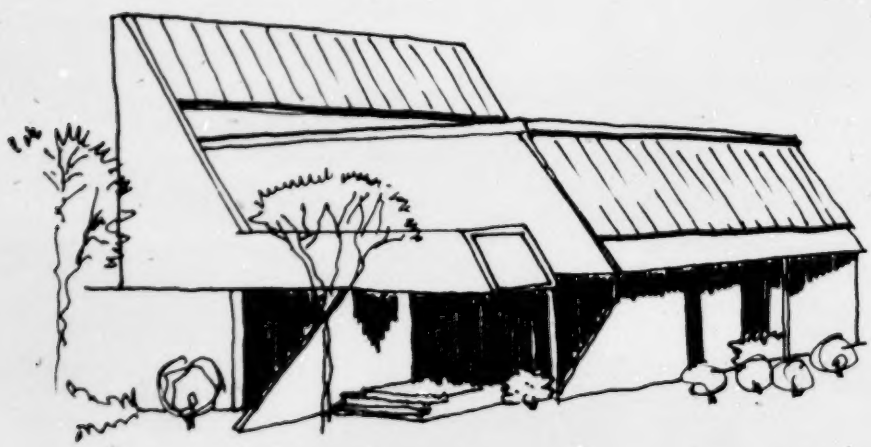

FIGURE 3 Phoenix Solar House.

system utilized 780 square feet of aluminum Roll-Bond absorber panel integrated with the roof structure. Dowtherm "J" was selected as the heat transfer medium because of its compatibility with the various materials in the system, its stability, and its low vapor pressure over a wide temperature range. An 8,000-gallon water storage tank with two internal heat exchangers for domestic hot water and the Dowtherm "J" in the solar collector loop provided for thermal storage; immersion resistance back-up heaters, controlled, to energize only in off-peak hours, also were provided. A conventional heat pump was used for supplementary heating and cooling. Charcoal filtering of the recirculated air was employed to reduce outside air requirements. The comparative costs per million Btu delivered were reported to be $0.17 for the solar collector/storage system, $1.75 for natural gas, and $3.50 for the heat pump. Under NSF sponsorship, the house was being instrumented for evaluation, and data from this instrumentation were to be collected automatically and transmitted via telephone to Honeywell in Minneapolis for computer processing. Surveys of visitors to the house indicated a generally favorable reaction to the design; however, homeowning visitors were concerned about the downpayment and total monthly payment costs of solar heated and cooled homes. For further information, contact Douglas Jardine, President, Phoenix of Colorado Springs, Inc., Colorado Springs, Colorado 80933, 303/633-2633.

Crowther, Kruse, McWilliams, Architects, designed the NSF/Colorado State University solar-heated and -cooled demonstration house and was engaged in the design and construction of several solar-heated and -cooled private residences in the Denver area. In these designs, the firm sought to combine energy-conservation design practices, the use of solar radiation through natural design methods, and the use of active solar collector systems. Two of these projects--both located on the same site in Denver--are described below:

1. A 1,100-square-foot retrofit project utilized roof-mounted solar air-heating collectors coupled with a pebble bed thermal storage unit located where the original coal bin had been. To further improve the thermal characteristics of the building, the exposed north wall was insulated by constructing a false wood wall in front of the original brick wall.

2. A 2,000-square-foot residence, designed to use wet collectors, made use of both electrostatic and activated charcoal filters to scrub recirculated air, thus reducing the outside air intake requirement. A greenhouse, adjacent to the south side of the house, provided natural humidity.

For further information, contact Richard L. Crowther, Crowther, Kruse, McWilliams, 2830 East Third Avenue, Denver, Colorado 80206, 303/355-2301.

Skytherm Processes and Engineering Company had its "Skytherm" design concept embodied in a 1,200-square-foot solar-heated and -cooled house constructed at Atascadero, California. The Skytherm design was intended to fill 100 percent of the house heating and cooling requirements at no or little increase in cost over a conventional heating and cooling system. For heating, the design concept utilized daytime absorption and storage of solar energy by plastic-covered water bags integrated into the roof structure. At night insulating covers were drawn

over the roof and the energy collected during the day re-radiated into the building interior. For summer, the system operated in reverse with the insulating covers used to reflect solar radiation during the day and the water bags used to absorb the heat from the interior of the house; at night the insulating covers were drawn open to allow the heat absorbed during the day to radiate to the night sky. California Polytechnical Institute, under contract to HUD, was evaluating the effectiveness of this approach. For further information, contact Harold Hay, President, Skytherm Processes and Engineering Company, 2424 Wilshire Boulevard, Los Angeles, California 90057, 213/389-2300.

With the joint sponsorship of The Ohio State University and the Homewood Corporation, Charles F. Sepsy was conducting a three-year experimental program expected to result in an assessment of the technical and economic practicality of utilizing solar energy in residential buildings. A test house was to incorporate available materials, energy-saving design features, solar energy collectors for heating and cooling, and built-in instrumentation to measure and record complete inside and outside environmental data. Being built on the Ohio State Fairgrounds, the 4-bedroom, 2-1/2 bath, 2,700-square-foot test house (Figure 4) was designed with exterior walls having only 3 percent window and four open courts to provide for interior lighting. Roof-mounted water/glycol-cooled flat-plate solar collectors, two 2,000-gallon underground tanks, and an Arkla absorption-type unit powered by solar collectors also were to be used with electric heaters supplementing the solar system. Other participants included C.D. Jones, G. Clark, R. Devore,

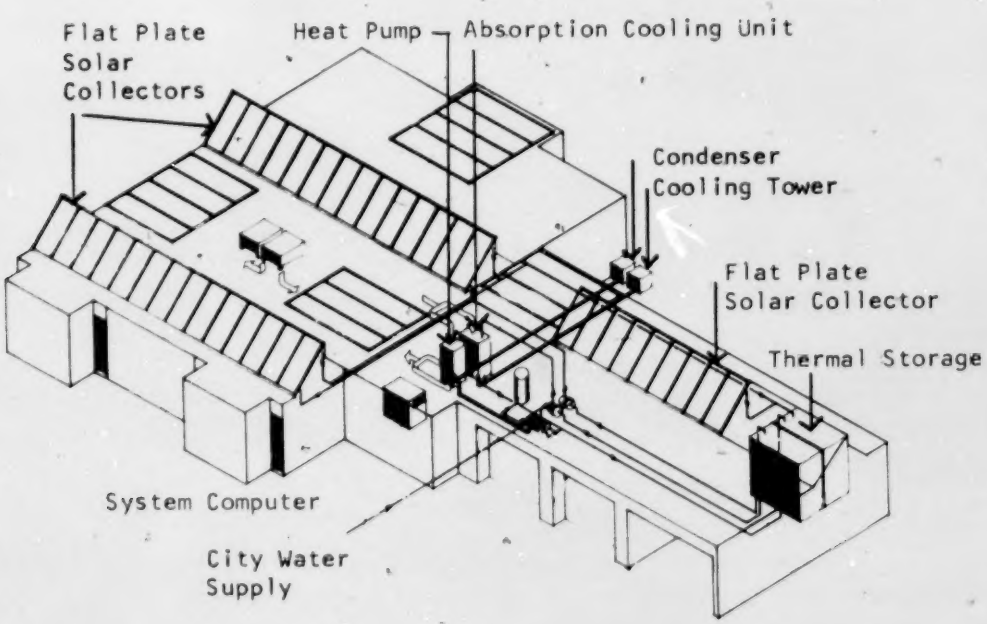

FIGURE 4 The Ohio State University Solar-Powered Test House.

and S. A. Mumma, The Ohio State University. For further information, contact Charles F. Sepsy, The Ohio State University, Department of Mechanical Engineering, Columbus, Ohio 43210, 612/422-6208.

The Decade 80 Solar House (Figure 5), designed by Arthur Kotch and being developed with Copper Development Association funding, was planned to be a 4-bedroom, 3-bath, 3,200-square-foot solar-energy demonstration house designed for energy conservation. A 2,000-square-foot water-cooled flat-plate solar collector, glass skinned and integrated with a copper roof and copper tubing for transport, was to be used in conjunction with a 2,500-gallon storage tank and two 3-ton solar-powered Arkla absorption units with a cooling tower. Energy savings of 60 percent were expected. Other participants included TRW, Inc., Consultants, Redondo Beach, California. For further information, contact Arthur Kotch, Architect, 6440 Hillcroft Street, Houston, Texas 77036, 713/771-2123.

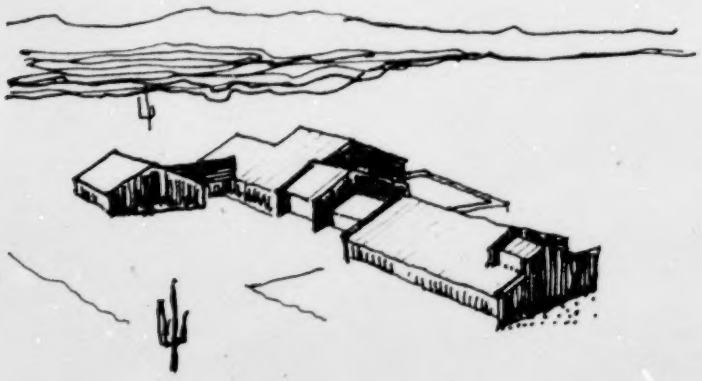

FIGURE 5 Copper Development Association Decade 80 Solar House.

Designed to conserve energy, a 2-story, 3-bedroom, 1-1/2-bath, 1,600-square-foot house was built in Allentown by the Pennsylvania Power and Light Company to determine "realistic energy-optimization possibilities" (Figure 6). The design goal was to decrease the energy requirements of an equivalent all-electric house by from 33 to 50 percent at a target cost of $35,000. A vertically mounted fence-style water/glycol-cooled flat-plate collector (in 3-foot by 3-foot or 2-foot by 4-foot modules) is used to gather solar heat for storage in a 1,000-gallon tank.

Two heat pumps and a 15-kW electric immersion heater in the storage tank supplement the solar energy. Heat also is recovered from the septic tank, bath water, refrigerator, washer, and dryer. Evaluation was to be completed and a report published in 1975. Other participants included the Franklin Institute Research Laboratories, Consultants, Philadelphia, Pennsylvania.

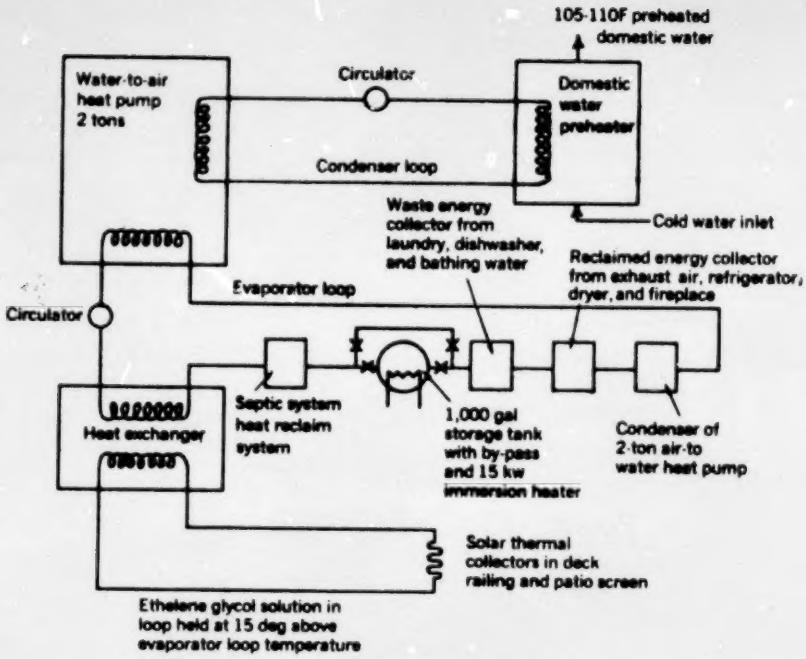
105-110F preheated domestic water
Water-to-air heat pump 2 tons
Circulator
Domestic water preheater
Condenser loop
Cold water inlet
Waste energy collector from laundry, dishwasher, and bathing water
Reclaimed energy collector from exhaust air, refrigerator, dryer, and fireplace
Evaporator loop
Circulator
Septic system heat reclaim system
Heat exchanger
1,000 gal storage tank with by-pass and 15 kw immersion heater
Condenser of 2-ton air-to water heat pump
Solar thermal collectors in deck railing and patio screen
Ethelene glycol solution in loop held at 15 deg above evaporator loop temperature

FIGURE 6 Schematic of Energy-Conserving Heating and Cooling System for Allentown Demonstration House.

For further information, contact Robert Romancheck, Research and Technical Service Department, Pennsylvania Power and Light Company, Allentown, Pennsylvania 18101, 251/821-5151.

An energy-conserving 1,000-square-foot single-family house (intended to sell for approximately $25,000 including land) was being built by Douglas Wilke, Architect, in Henniker, New Hampshire, to demonstrate solar-energy heating and air-dehumidification cooling. Energy was to be supplied by 700 square feet of roof-mounted air-cooled flat-plate solar collectors, and dehumidification of incoming air was to be achieved by scrubbing with triethylene glycol, a process widely used in industry and being adapted for residential cooling. Prototype equipment was to be used in the demonstration house. Other participants included Erwin Logwig, Niagra Blower Company, New York, New York, and George Lof, Solar Consultant, Ft. Collins, Colorado. For further information, contact Douglas Wilke, 38 Roosevelt Avenue, Glen Heat, New York 11545, 516/759-9050.

To develop and demonstrate a packaged solar-energy system for purchase and installation by local builders and heating/ventilation/air-conditioning contractors, seven single-family houses with integrally roof-mounted air-cooled solar collectors to provide for space heating were being built in

San Diego, California, by Energy Systems, Inc. A below-grade rock pile was to provide for thermal storage and various solar-collector/heating-system configurations were to be applied to determine the optimal design for the package system. Eventually intended for nationwide distribution, the system was expected to provide 50 percent of the space heating for houses of up to 3,000 square feet. For further information, contact Terrance R. Caster, President, Energy Systems, Inc., 634 Crest Drive, El Cajon, California 92021, 714/440-4646.

ILS Laboratory, a group of engineers and scientists interested in energy-conservation designs, had built an energy-conserving house in Tijeras, New Mexico. The igloo-type structure was 31 feet in diameter and heavily insulated. Ground-mounted water/glycol-cooled flat-plate solar collectors provided 100 percent of the heating requirements and an underground tank was used for storage. For further information, contact Robert G. Reines, ILS Laboratory, Star Route 103, Tijeras, New Mexico 87059, 505/281-5191.

Donald Watson, AIA, was designing and building a house in Guilford, Connecticut, using energy-conserving design and a solar collector. Energy-conserving techniques included optimum orientation, shading, insulation, window shuttering, and heat recovery from refrigerator coils and sewage tank. The 2-story, 1,900-square-foot house featured 456 square feet of water/glycol-cooled flat-plate collectors integrally mounted in the roof.

Enough thermal storage for 1-1/2 days of operation was provided by 2,000-gallon storage tanks while an oil-fired water heater supplemented the solar-energy system. Other participants included Everett Barber, a solar engineer and the owner of the residence. For further information, contact Donald Watson, AIA, Box 401, Guilford, Connecticut 06437, 203/453-6388.

Burt, Hill and Associates, Architects, were designing a 2-bedroom, 2-bath, 1,400-square-foot, 3-level house in Shanghai, West Virginia, featuring 588 square feet of water/glycol-cooled flat-plate solar collectors integrally mounted in the roof structure at a 45 degree angle (Figure 7). Storage at two temperature levels was to be provided by two tanks, one 2,400 gallons and the other 400 gallons. An oil-fired water heater would supplement the system, which was designed for the future addition of an absorption air-conditioning unit. Other energy-conserving design features included triple glazing in windows, an air-lock entrance, and a central fireplace. Other participants included Mrs. A. N. Wilson, the owner of the house. For further information, contact Paul Richard Rittleman, AIA, Burt, Hill and Associates, Architects, 610 Mellon Bank Building, Butler, Pennsylvania 16001, 412/285-4761.

Richard L. Crowther was remodeling a 2,000-square-foot house in Denver, Colorado, to demonstrate such passive energy-conservation techniques as control of surface coating absorptivity, optimum window area, and use of natural ventilation (Figure 8). For further information, contact Richard L. Crowther, 500 Cook Street, Denver, Colorado 80206, 303/388-1875.

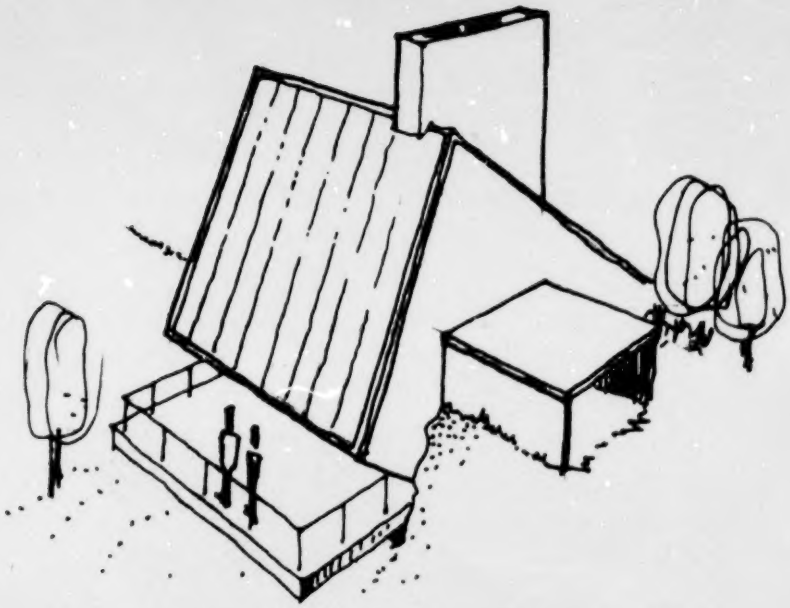

FIGURE 7 Solar-Energy House in Shanghai, West Virginia.

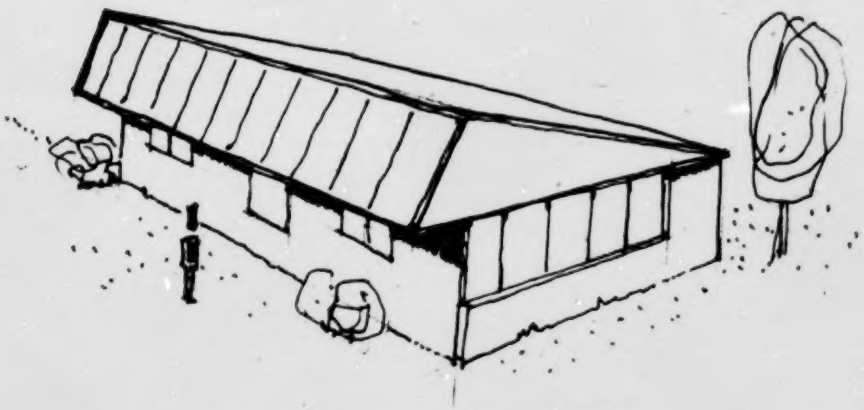

FIGURE 8 Retrofitted House for Solar-Energy Use in Denver, Colorado.

Bob Schmitt Homes, Inc., had completed a 3,600-square-foot single-family residence designed to provide optimum heat-loss-and-gain reduction through improved thermal characteristics and solar-energy control. The house featured a 1,100-square-foot central atrium with skylights. Surrounding living areas used glass in walls facing to the atrium to allow heat collected and stored in the atrium to be reradiated into living areas during cold weather. During warm weather the skylights were shaded and living areas lost heat via naturally induced ventilation through the atrium. Exterior walls were void of glass and additional insulation is used throughout. Air infiltration through window and door cracks is minimized and attic temperatures are controlled by a fan and louvers. An electric heat pump supplies supplementary heating and cooling. Additional houses were being developed for sale. Other participants included Edward A. Schmitt, Architect, Strongville, Ohio. For further information, contact Bob Schmitt, Bob Schmitt Homes, Inc., 13079 Falling Water, Strongville, Ohio 44136, 216/238-6915.

Design Plus was retrofitting an existing 2,000-square-foot house in Colorado Springs with a solar collector consisting of vertically mounted rectangular panels used also as a yard fence. Using 240 square feet of fence-style water/glycol-cooled flat-plate collectors in ten 4-foot-by-6-foot modules with adjacent aluminum reflector panels for additional solar radiation pickup, the system was designed for application to existing residences and provision was made for the addition of collector panels as needed. Two 1,000-gallon below-grade tanks provided thermal storage. Other participants included James Sinton, the owner of the house. For further information, contact Byron Bloomfield, Design Plus, 1709 Woodmoor Drive, Moment, Colorado 80132, 303/481-3656.

C. PRODUCT/SYSTEM DEVELOPMENT

Francis Wessling of the University of New Mexico at Albuquerque, on his own initiative and with some financial support from the New Mexico Four Corners Commission, was developing low-cost passive solar heating systems that utilized the adobe or rock wall structures found in the New Mexico area. Having developed a computer program to analyze the effectiveness of adobe and rock wall structures as solar collector and thermal storage devices (particularly when covered with glass and painted black), he maintained that this type of system was capable of providing solar heating at an equivalent cost of $1 and 2 per square foot. For further information, contact Professor Francis Wessling, Department of Mechanical Engineering, University of New Mexico, Albuquerque, New Mexico 87106.

The California Institute of Technology's Jet Propulsion Laboratory was involved in the two major projects funded by local public utilities described below:

1. The Southern California Edison Company project was mounted to determine which of several alternative applications of solar energy will be the most beneficial to the company and its customer.

2. Project SAGE was funded by Southern California Gas Company to determine the feasibility of commercializing solar water-heating units for multifamily dwellings. These hot water units would be owned and maintained by the public

utility, which then would supply energy to the owner or tenant on either a rent, lease, or Btu basis. The development and evaluation of several solar water heater designs was being completed (see Figure 9 for an example) and the next step was to be to integrate the solar hot water heater system into existing and new apartment buildings. Long-term plans called for the establishment of a commercial venture for the installation of up to 5,000 solar hot water heater units per year in the southern California region starting by 1977. For further information, contact Edgar S. Davis, Program Manager, California Institute of Technology, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91103, 213/354-7004.

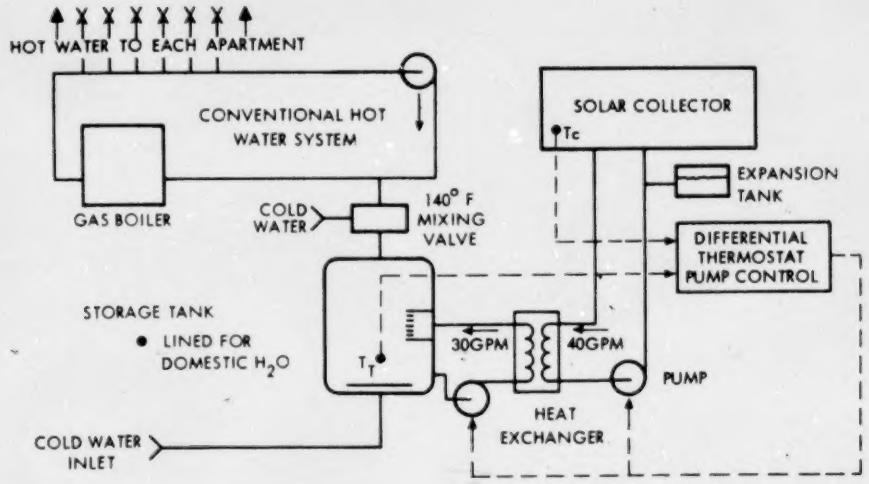

FIGURE 9 Solar-Assisted Gas Energy Water Heater System.

PPG Industries was producing and marketing 3-foot-by-6-foot aluminum wet collectors ($6 to 7 per square foot). The baseline collector also could be purchased in mild steel ($9 to 10 per square foot) or copper ($12 to 13 per square foot) on a custom order basis. Production capacity for the aluminum collector was limited but additional production capacity was to be increased to 3 million square feet per year. PPG also was involved in research and development efforts aimed at reducing costs and increasing reliability. For further information, contact Ray Gallagher, Project Manager, PPG Industries, One Gateway Center, Pittsburgh, Pennsylvania 15222, 412/434-3553.

Schultz-Field Enterprises, General Contractors, had constructed several San Diego area homes that utilized either solar-heated hot water systems, solar distillation units, solar space-heating systems, or combinations of these. In order to ensure compliance with Uniform Building Code recommendations and subsequent acceptance by the San Diego building code authorities, the firm had

begun manufacturing its own solar collectors composed of stainless steel tubing on aluminum absorber panel. For further information, contact Jack Schultz, President, Schultz-Field Enterprises, 6986 La Jolla Boulevard, La Jolla, California 92307, 714/454-1312.

Sunwater Company, a manufacturer of solar water heaters and solar distillation units for over 15 years, had recently designed and installed several for space-heating systems in the San Diego area including a low-cost (under $200) novel combination air collector and pebble bed thermal storage system that was used to retrofit a typical low-income adobe house in the rural Southwest. This system supplied approximately one-half of the total heat requirements formerly supplied by bottled gas. For further information, contact Horace McCracken, President, Sunwater Company, 1112 Pioneer Way, El Cajon, California 92020, 714/440-3151.

The Solaron Corporation manufactured, marketed, and distributed solar heating and cooling components and systems utilizing air collectors and pebble bed storage units for both residential and commercial applications. The product line included the collectors, pebble bed storage unit, electronic control system, air handling system, hot water heater, day-night heat exchanger or nocturnal cooler auxiliary heating unit, and interconnecting ducts and wiring ready for installation. Packaged systems for use by any HVAC contractor or modular components for use in engineered systems were available. All systems were designed and intended to be installed in accordance with standards and procedures produced by Solaron. In addition, Solaron provided consulting advice and systems analysis services to prospective clients. Projects under construction included custom-built residences, retrofitted residences, and light commercial buildings. Designs under way included planned unit developments, multifamily residential buildings, public buildings, and large tract residential housing. For further information, contact John Bayless, President, Solaron Corporation, 4850 Olive Street, Denver, Colorado 80022, 303/289-2288.

Enerjex Corporation manufactured and distributed complete wet-collector modules utilizing both copper and aluminum absorber panels with selective absorbing surfaces. These collectors had been installed in several buildings in the Las Vegas, Nevada, area and also were being distributed on a nationwide basis. For further information, contact Alfred Jenkins, President, Enerjex Corporation, 5115 South Industrial Road, Las Vegas, Nevada 89103, 702/736-2994.

International Solarthermics Corporation manufactured and marketed an integrated solar heating module composed of solar air collectors and a pebble bed thermal storage unit, circulating fans, and controls packaged in a single-grade-mounted unit. The system primarily was designed for the retrofitting of existing homes but also was applicable in new construction. The firm believed that its air collectors and rock storage systems offered advantages in retrofitting residential housing because of the system's high reliability and low maintenance requirements, the fact that the system was more compatible with the forced-air heating systems used in 80 to 95 percent of existing houses, and the additional thermal storage capacity inherently available in rock storage units due to a

lower "down point" temperature (i.e., forced-hot-air systems could circulate air at a minimum down point temperature of 75° F while hydronic systems require a minimum down point temperature of 110° F). Solarthermics was developing a system for direct solar energy conversion to shaft horsepower and an improved solar collector capable of more efficiently collecting the diffused component of solar radiation. For further information, contact John Keyes, Chairman of the Board, International Solarthermics Corporation, P.O. Box 397, Nederland, Colorado 80466, 303/258-3272.

William B. Harris of Texas A&M University was working to identify opportunities for application of the Solaterre system concept (Figure 10) involving use of a patented solar collector to heat large quantities of well water during warm weather and storage of the water in an underground reservoir for distribution during winter to houses and buildings in a community. The system concept also provided for cooling water with spray ponds during cold weather and storing it for distribution during warm weather. Other participants included Richard R. Davidson of Texas A&M University. For further information, contact William B. Harris, Texas A&M University, Department of Chemical Engineering, College Station, Texas 77843, 713/845-3361.

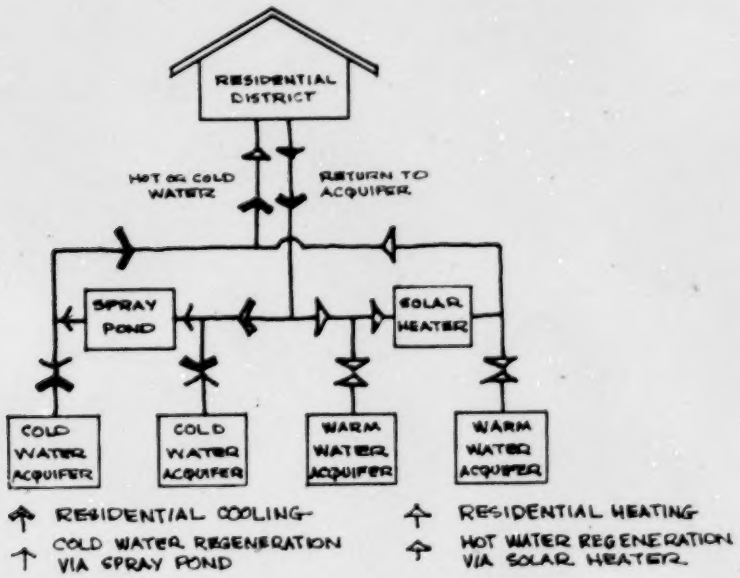

FIGURE 10 Schematic of Solaterre System.

D. GENERAL PROJECTS AND ACTIVITIES

Materials Consultants, Inc., had recently completed retrofitting two homes for solar heating at the U.S. Navy installation in Hawthorne, Nevada, and was involved in solar collector research, materials evaluation, and policy development studies in the solar heating and cooling area. For further information, contact Jerry Plunkett, President, Materials Consultants, Inc., 2150 S. Josephine Street, Denver, Colorado 80210, 303/722-8258.

Atif S. Debs of the Georgia Institute of Technology was conducting a study to determine whether a combination of roof-mounted flat-plate solar collectors and underfloor collapsible thermal storage tanks in a mobile home could provide 50 percent of the total heating requirements. For further information, contact Atif S. Debs, Georgia Institute of Technology, Engineering Experiment Station, Atlanta, Georgia 30302, 404/894-3411.

Jerome Weingart and Richard Schoen of the University of California, with Ford Foundation Energy Policy Project funding, were describing institutional constraints to the implementation of solar heating and cooling technology in building. For further information, contact Jerome Weingart and Richard Schoen, University of California, Los Angeles, California 90007, 213/825-4321.

Arthur D. Little, Inc., was conducting a three-phase, two-year study with the sponsorship of more than 80 firms. Phase I involved identification of successful businesses in the solar-climate control industry and determination of prerequisites and methods for integrating them into the building industry. During Phase II, hardware was to be evaluated and detailed marketing plans formulated while the participating firms were to collaborate during Phase III to implement the marketing plans. For further information, contact Joan Berkowitz, Arthur D. Little, Inc., 20 Acorn Park, Cambridge, Massachusetts 02140, 617/864-5770.

III

NEEDS OF THE BUILDING COMMUNITY

The nonproprietary technical information and research needs and the societal and institutional, building design and construction, and product design and manufacture constraints to widespread application of solar heating and cooling as perceived by the private sector of the building community are identified below. These expressions of need and concerns reflect the comments of participants in the Tempe workshop and the responses to the mail survey conducted shortly after that workshop.

A. NONPROPRIETARY TECHNICAL INFORMATION AND RESEARCH NEEDS

1. Technical Information Needs

Workshop participants identified the lack of certain kinds of scientific and engineering information as constituting a constraint to wider application of solar energy for the heating and cooling of buildings. Often cited among the information needs were meteorological information applicable at a particular building site and physical property information concerning solar collector materials, rock bed thermal storage systems, and building wall assemblies. With regard to meteorological information, it was pointed out that in order to estimate the quality and quantity of solar radiation at a specific proposed building extensive and dubious interpolations must be made from the data on weather (e.g., cloud cover, available sun, wind speed and direction, and air temperature) currently collected at widely spaced U.S. Weather Bureau stations. With regard to physical properties information concerning solar collector materials, it was noted that available information about the performance of various metals, plastics, coatings, sealants, glasses, energy transfer chemicals, and the various combinations of these materials was insufficient with respect to such matters as their degradation characteristics in terms of resistance to long-term exposure to air-borne elements (e.g., NO_x, SO_2, CO, CO_2, and H_2O), their efficiency in transmitting or absorbing the spectrum of incident radiant energy, and their stress/strain characteristics under conditions such as daily cyclical loading and large temperature differentials. With regard to rock bed thermal storage systems, it was indicated that available physical properties information was inadequate concerning such matters as specific heat of granular materials and the relationship between the porosity of the granular mass and its thermal conductivity. Available physical properties information about building wall assemblies was deemed to be lacking in data on the thermal performance of full-size component assemblies under the full range of dynamic environmental conditions to which they may be exposed in use.

Workshop participants also indicated that the lack of cost and performance experience data on solar heating and cooling installations constrain wider application of solar energy systems by hampering the design of efficient systems at costs sufficiently low to be competitive with conventional heating and cooling systems for buildings. It was noted, for example, that basic product information on available solar systems, components, and controls are not well disseminated (i.e., there is a lack of "resource" catalogs detailing available solar heating and cooling equipment and appurtenances).

In the mail survey conducted subsequent to the Tempe workshop, the most frequently cited problem with regard to the design of solar heating and cooling systems was the lack of specific cost and design data. Of the 32 engineers, architects, builders, code officials, and mobile home manufacturers who responded to the survey and had specific experience in the design of solar heating and cooling systems, 18 cited this problem. A companion problem cited by 14 respondents was the lack of information on similar applications. In addition, of the total 280 engineers, architects, builders, code officials, and mobile home manufacturers who responded to the survey, 148 respondents cited lack of data on performance and reliability of solar equipment and 94 cited lack of technical data and/or design procedures as being among their reasons for not having participated in any solar heating or cooling activities.

2. Research Needs

Workshop participants noted that some of those information needs identified above could be met merely by effecting better information collection and dissemination processes. They noted, for example, that a significant improvement in the quality and quantity of meteorological information could be had by increasing the number of meteorological-data-gathering stations and by expanding the list of routine measurements to be made at these stations to include such items as pyrheliometric measurement of the solar energy coming directly from the solar disc and pyranometric measurements of the total solar energy available (direct from the solar disc plus the diffuse component from the sky which is reflected off of clouds and other surfaces within the hemisphere).

The workshop participants also indicated, however, that better information collection and dissemination processes would not fill most of the identified information needs and that increased research activity was necessary in these areas. Additional research was deemed particularly necessary to provide the needed physical properties information. For example, the participants noted that only limited investigations had been made of how some "everyday" materials (e.g., glass, plastics, metals, and chemical fluids) function when used in nontraditional combinations under the thermal and physical loading conditions that arise in a solar heating and cooling system. Further, they noted that considerable research and development were needed:

a. To improve solar collector technology so that bulky arrays were not needed to heat the working fluid (air, water, or some other fluid) to the 170 °F ± (77 °C ±) necessary for home heating and to the 240 °F ± (116 °C ±) necessary for home air conditioning--the latter not having been achieved by solar systems available in the market.

b. To improve the energy storage capabilities of solar heating and cooling systems because available collectors work inefficiently, if at all, on overcast or rainy days and available energy storage systems were cumbersome and had relatively limited (one to three days) heat storage/release capabilities.

c. To improve the operation of the control systems that interlock the collector, heat transfer, and heat storage subsystems of a solar heating and cooling system and to reduce the complexity and cost of these systems.

In the survey conducted subsequent to the workshop, the most frequently cited problem with regard to the operation and maintenance of solar heating and cooling systems was collector failure--specifically, the freezing of working fluid circulation tubes and absorber degrading. Of the 32 engineers, architects, builders, and code officials who responded to the survey and had specific experience in the design of solar heating and cooling systems, 5 respondents cited this problem. Other problems cited by this class of respondents were lack of heating and cooling capacity, general degradation of materials, unreliable components, and collector failures due to acts of God or vandalism.

B. AREAS OF CONCERN

1. Societal and Institutional Constraints

Workshop participants called attention to the lack of a clear commitment by the government to use solar energy for heating and cooling buildings as being the major constraint to substantially wider application of solar systems. They alleged that without such a commitment the increase in public and private investment and consumer funds needed to support solar energy research, development, production, and sales would not occur. They emphasized that such a commitment would need to reflect a decision to remove the restrictions on the price of fossil fuels so that these fuel prices will move higher and thus make the cost of solar systems more competitive with conventionally fueled heating and cooling systems as well as a decision to provide the following kinds of incentives:

a. Income tax deductions for or credits to consumers who install solar energy systems.

b. Direct subsidies to builders and developers to partially off-set costs of solar energy installations.

c. Guarantees of mortgages or low-interest loans to consumers, inventors, builders, and developers borrowing to finance solar energy development and installation.

d. Exemptions from sales taxes to purchasers of solar energy systems.

e. Government guarantees to insurance companies for underwriting policies covering damage from fire, hail, wind, vandalism, etc., for consumers who own solar energy systems.

f. Tax credits to inventors, manufacturers, builders, and others for investment of capital funds in solar energy systems development.

g. Accelerated depreciation tax benefits to producers of solar energy systems and production equipment.

The participants in the workshop also identified the practices of public utility corporations and state regulatory commissions as being impediments to wider application of solar heating and cooling systems. They alleged that utility rate structures applicable to residences favored energy consumption and thereby thwarted sales promotions based on higher initial cost/lower operating cost arguments. Further, they alleged that utility rate structures and investment criteria limited the amount of funds invested in solar energy research and development to that which could be expected to be amortized in a short (approximately five-year) period and thereby minimized the solar energy research and development activity focused on application of solar energy in individual houses.

Workshop participants also noted that, in at least one respect, local building codes and zoning practices impeded wider application of solar heating and cooling systems. While acknowledging that there are legal precedents concerning the rights of property owners to access to solar energy, the participants claimed that legal issues were not sufficiently delineated to assure potential purchasers of solar systems that they will have sufficient, continued, unobstructed access to available solar energy. The workshop participants additionally noted that manpower problems--lack of architects and engineers with applicable education and experience to design solar systems, craft union jurisdictional disputes, and lack of skilled craftsmen to fabricate, install, and maintain solar systems--were an impediment to wider application of solar heating and cooling systems.

In the survey conducted subsequent to the Tempe workshop, 142 of the 280 engineers, architects, builders, code officials, and mobile home manufacturers who responded listed "no apparent client or market interest" as one of their top three reasons for not participating in any solar heating and cooling activities; 94 of the respondents also listed "lack of technical competence," 85 listed "not economically feasible," and 21 listed "high degree of risk." There were a scattering of other citations as one of the top three reasons for not participating in any solar heating and cooling activities; some of these were "have not been approahced," "never had a request for permit," "have had no inquiry in this area," "clients are interested but wary of financing and cost," "no interest on part of government to promote," "liability exposure," "penalty from utility company," "other energy sources available now and in the future," "use cheap power," "use coal, no power shortage," and "price of natural gas so low there is no incentive to even insulate." A scattering of responses

also mentioned financing, manpower availability, code issues, and utility rate structures as creating problems in applying solar energy to the heating and cooling of buildings but noted that these problems were not nearly as significant as those engendered by lack of interest and cost.

2. Building Design and Construction Constraints

In addition to the technical information and research needs identified above, the workshop participants called attention to a number of other problem areas in the design and construction of solar energy heating and cooling systems. They particularly emphasized that the lack of design procedures and system/product performance criteria and evaluation procedures mitigate against accelerated application of solar energy and indicated that this lack precluded meaningful exchanges of information about performance needs and costs and of technical experience among interested parties. Additionally, they noted that the lack of generally accepted design procedures forced designers to begin each design assignment with development of the procedures to be used, thus adding to the time required and cost entailed in the application of solar energy to a particular building. Also mentioned was the lack of performance criteria and evaluation procedures applicable to solar heating and cooling systems and components, which engendered distrust of the claims of producers and, coupled with the absence of significant data about prior system/component performance, led to inappropriate applications of systems and components. Further, they mentioned that the dearth of "off-the-shelf" systems and components and the limited number of producers/distributors of systems and components caused individualistic design solutions to be proposed for each building, thus complicating design and construction procedures and adding to the time required and cost entailed in applying solar energy.

In the survey conducted subsequent to the workshop, after the problem of lack of specific cost and design data, the problems in the design of solar heated and cooled buildings most frequently cited focused on the lack of design procedures, solar equipment suppliers, and information on similar applications. Of the 280 engineers, architects, builders, code officials, and mobile home manufacturers who responded to the survey, 64 cited lack of design procedures, 63 cited lack of solar equipment, and 55 cited lack of information on similar applications as one of the top three problems encountered in design. Of the 32 engineers, architects, builders, code officials, and mobile home manufacturers responding who possessed specific experience with solar heating and cooling systems, 14 cited lack of information on similar applications, 13 cited lack of design procedures, 13 cited lack of solar equipment supplies as one of the top three design problems. Significantly, of the 280 respondents, 85 cited economic infeasibility of solar heating and cooling systems as one of their top three reasons for not participating in any solar heating and cooling activities.

3. Product Design and Manufacture Constraints

Workshop participants identified a number of problems--in addition to information and research needs--that adversely affect the design and manufacture of solar

heating and cooling systems and components. They cited, for example, the lack of a sufficiently identifiable aggregated market as one of the reasons for there not being more and better designed stock systems and components available. They also noted that, particularly from the viewpoint of the small company that had heretofore not been part of the traditional building community, the lack of sufficient capital to support protracted product research and design efforts and the lack of established product distribution networks are further substantive reasons for there not being more and better designed stock products available.

In the survey conducted subsequent to the workshop, the two most frequently enumerated problems of the solar equipment manufacturers were the lack of working capital and the lack of an aggregated market. Of the 43 manufacturers who responded, 18 cited the working capital problem and 15 cited the market problem as being among the top three problems.

APPENDIX A

PARTICIPANTS IN THE WORKSHOP ON SOLAR HEATING AND COOLING OF BUILDINGS

December 9, 1974
Tempe, Arizona

Speakers

HERMAN BARKMANN, President, Barkmann Engineering, Santa Fe, New Mexico
JOHN C. BAYLESS, President, Solaron Corporation, Denver, Colorado
FRANK H. BRIDGERS, Bridgers and Paxton, Albuquerque, New Mexico
RICHARD L. CROWTHER, Crowther, Kruse, McWilliams, Denver, Colorado
E. S. DAVIS, Program Manager, California Institute of Technology/Jet Propulsion Laboratory at Pasadena
RAY GALLAGHER, Project Manager, PPG Industries, Pittsburgh, Pennsylvania
H. R. HAY, President, Skytherm Processes and Engineering Company, Los Angeles, California
DOUGLAS M. JARDINE, President, Phoenix of Colorado Springs, Inc., Colorado
ALFRED JENKINS, President, Enerjex Corporation, Las Vegas, Nevada
JOHN M. KEYES, Chairman of the Board, International Solarthermics Corporation, Nederland, Colorado
HORACE McCRACKEN, President, Sunwater Company, El Cajon, California
JERRY D. PLUNKETT, President, Materials Consultants, Inc., Denver, Colorado
JACK SHULTZ, President, Shultz-Field Enterprises, LaJolla, California
ELMER R. STREED, Mechanical Engineer, National Bureau of Standards, Center for Building Technology, Washington, D.C.
FRANCIS C. WESSLING, Professor, Department of Mechanical Engineering, University of New Mexico at Albuquerque

Guests

JACK H. BRADY, Chenault, Brady and Freeman, Consulting Engineers, Dallas, Texas
WILLIAM L. PETTY, Rogers, Nagel, Langhart, Architects and Engineers, Denver, Colorado
FRANK SHERIDAN, Sunwater Company, El Cajon, California
LEE WINDHEIM, Senior Vice President, Leo A. Daly Company, San Francisco, California

BRAB Committee Members

FRED S. DUBIN
EUGENE R. HARRIS
ROBERT E. HENDERSON
RALPH J. JOHNSON
BERNARD P. SPRING
WILLIAM G. WAGNER
JOHN I. YELLOTT
JOSEPH H. ZETTEL

APPENDIX B

QUESTIONNAIRES USED IN MAIL SURVEY AND TABULATION OF RESPONSES

Copies of the questionnaires used in the mail survey conducted subsequent to the December 1974 workshop conclude this appendix. Of the 1,563 questionnaires distributed, 323 individuals responded--110 engineers, 57 architects, 64 code officials, 39 homebuilders, 10 mobile home manufacturers, and 43 solar heating and cooling system and component manufacturers.

Table 1 categorizes the respondents by geographical location and identifies the number of respondents indicating prior experience in solar heating and cooling activities. Table 2 categorizes the responses of those 205 individuals without solar-related experience to the question concerning their reasons for not having participated in such activities (see page 6 of Questionnaire A). Table 3 categorizes the responses of all 280 engineers, architects, code officials, homebuilders, and mobile home manufacturers to the question concerning the problems they had encountered in the design, construction, or operation of solar heated and cooled buildings (see page 6 of Questionnaire A). Table 4 categorizes the responses of all 280 engineers, architects, code officials, homebuilders, and mobile home manufacturers to the question concerning the types of technical, economic, and institutional problems that require attention before solar heating and cooling systems receive wider use (see page 7 of Questionnaire A). Table 5 categorizes the responses of all 280 engineers, architects, code officials, homebuilders, and mobile home manufacturers to the question concerning the types of technical, economic, and institutional actions to be taken in order to encourage wider use of solar heating and cooling systems in buildings (see page 8 of Questionnaire A). Table 6 categorizes the responses of all 280 engineers, architects, code officials, homebuilders, and mobile home manufacturers to the question concerning the organizations or institutions best able to implement the recommended actions to encourage solar heating and cooling of buildings (see page 9 of Questionnaire A). Table 7 categorizes the responses of the 43 equipment manufacturers to the question concerning the types of problems they had encountered (see page 4 of Questionnaire B). The 43 equipment manufacturers also were asked about the types of technical and economic actions to be taken in order to encourage wider use of solar heating and cooling systems in buildings and the organizations or institutions best able to implement the recommended actions. Responses to these questions were so varied and incomplete that tabulations would prove valueless; the responses were used, however, as input to the preparation of section III of the report.

TABLE 1 Categorization of Respondents by Geographical Location and Prior Experience in Solar Heating and Cooling Activities

Geographic* Region	Number of Respondents: Engineers Total	Engineers Exp.	Architects Total	Architects Exp.	Code Officials Total	Code Officials Exp.	Homebuilders Total	Homebuilders Exp.	Mobile Home Mfgrs. (none exp.)	Equipment Mfgrs. (all exp.)	All Total	All Exp.	Number of Questionnaires Mailed: Equipment Mfgrs.	Total
I	6	1	4	0	4	0	4	0	0	8	26	9	15	108
II	18	6	4	0	3	0	2	0	0	5	32	11	9	132
III	14	5	1	0	15	3	4	0	0	3	37	11	17	183
IV	21	0	10	1	21	3	9	0	3	3	67	7	7	336
V	12	0	14	3	11	1	8	0	7	7	59	11	14	301
VI	7	2	6	0	8	0	4	0	0	2	27	4	6	166
VII	6	1	6	0	1	0	2	0	0	0	15	1	1	92
VIII	7	1	2	0	1	0	1	1	0	3	14	5	6	73
IX	9	1	7	1	0	0	1	0	0	12	29	14	25	104
X	10	1	3	1	0	0	4	0	0	0	17	2	0	68
Total	110	18	57	6	64	7	39	1	10	43	323	75	100	1563

*Regions are identical with U.S. Government Organization Manual 1975/1976, U.S. Government Printing Office 1975

TABLE 2 Reasons for Not Participating in Solar Heating and Cooling Activities Categorized by Kind of Respondent

Reason	Number of Times Cited as Being One of Top Three Reasons					
	Engineers	Architects	Code Officials	Home Builders	Mobile Home Mfgrs.	Total
No apparent client or market interest	41	29	40	27	5	142
Local codes and zoning practices	0	1	2	3	2	8
Not economically feasible	34	19	14	16	2	85
Lack of data on performance and reliability of solar equipment	47	38	23	34	6	148
Lack of technical competence and/or design procedures	20	30	19	22	3	94
High degree of risk	5	5	3	6	2	21
Other	12	15	19	8	1	55

TABLE 3 Problems Encountered in the Design, Construction, and Operation of Solar Heated and Cooled Buildings Categorized by Kind of Respondent and Prior Experience in Solar Heating and Cooling Activities

Problem	Number of Times Problem Cited by Respondents										
	Engineers		Architects		Code Officials		Homebuilders		Mobile Home Mfgrs.	Total	
	All	Exp.	All	Exp.	All	Exp.	All	Exp.		All	Exp.
With Regard to design:											
Lack of available design procedures	25	5	19	4	11	3	9	1	0	64	13
Lack of solar equipment supplies	37	8	14	2	6	3	4	0	2	63	13
Lack of specific cost and design data	33	9	20	4	9	4	9	1	2	73	18
Lack of information on similar applications	22	5	17	5	8	3	6	1	2	55	14
Codes and zoning restraints	0	0	0	0	1	0	1	0	0	2	0
Integration of solar equipment and building architecture	10	4	4	0	3	2	3	0	0	20	6
Other	19	5	3	1	3	2	4	0	0	29	8
With regard to construction:											
Lack of skilled labor	3	0	2	0	1	1	3	0	0	9	1
Labor disputes	0	0	0	0	1	0	0	0	0	1	0
Solar collector assembly or installation problems	8	2	4	0	3	1	0	0	1	16	3
Scheduling	1	0	0	0	0	0	0	0	1	2	0
Code, health, and safety problems	0	0	0	0	2	0	0	0	1	3	0
Cost overrun	5	2	2	1	0	0	0	0	0	7	3
Financing	5	1	2	1	0	0	0	0	0	7	2
Installation and checkout	0	0	0	0	1	0	0	0	0	1	0
Other	1	0	1	1	2	2	3	0	0	7	3
With regard to operation and Maintenance:											
Lack of (or excessive) heating or cooling capacity	3	2	2	0	0	0	0	0	0	5	2
Materials degradation	2	2	0	0	1	0	0	0	0	3	2
Poorly designed or unreliable system components	0	0	5	1	2	1	0	0	0	7	2
Owner or operator misuse	3	2	1	0	1	1	0	0	0	5	3
Equipment failures (other than collectors)	1	0	1	0	0	0	0	0	0	2	0
Collector failures	23	10	3	0	7	4	3	0	0	36	14
Other	0	0	1	0	1	1	1	0	0	3	1

TABLE 4 Problems Requiring Further Attention Before There Can Be Wider Use of Solar Heating and Cooling Systems Categorized by Kind of Respondent and Prior Experience in Solar Heating and Cooling Activities

Problem	Number of times Problem Cited										
	Engineers		Architects		Code Officials		Homebuilders		Mobile Home Manufacturers	Total	
	All	Exp.	All	Exp.	All	Exp.	All	Exp.		All	Exp.
With regard to technical matters:											
Components (collectors, thermal storage, materials, etc.)	36	11	11	3	3	1	4	0	1	55	15
System (design, performance, reliability, etc.)	24	6	16	3	10	3	4	1	2	56	13
Information (components, system and component design, environment, etc.)	37	10	29	3	13	2	17	1	4	100	16
Qualification (system or component)	6	2	1	1	1	0	1	0	0	9	3
Operational (use, control, etc.)	7	2	7	1	5	2	2	1	0	21	6
Other	4	1	5	1	4	3	2	0	0	15	5
With regard to economic matters:											
High first cost	25	8	11	2	9	4	5	0	3	53	14
Market aggregation	3	1	2	0	1	0	3	0	2	11	1
Incentive Methods	15	4	9	1	7	0	1	0	1	33	5
Financing Methods	9	2	4	0	3	0	3	0	1	20	2
Utility rate structure	6	1	9	1	3	0	3	1	1	22	3
Other	2	2	1	0	0	0	3	0	0	6	2
With regard to institutional matters:											
Codes and zoning practice	2	1	5	0	5	0	5	0	1	18	1
Labor and skill training	4	2	4	0	1	0	2	0	0	11	2
Public acceptance	8	0	12	0	11	4	8	1	3	42	5
Lending institution acceptance	7	2	7	2	7	1	4	0	1	26	5
Other	1	0	1	0	1	1	2	0	0	5	1

TABLE 5 Kind of Actions Recommended To Encourage Use of Solar Heating and Cooling in Buildings

	Engineers		Architects		Code Officials		Homebuilders		Mobile Home Mfgrs.	Total	
	All	Exp.	All	Exp.	All	Exp.	All	Exp.	(none exp.)	All	Exp.
Technical Recommendation											
Further R & D	71	14	40	6	20	11	15	3	7	153	140
Development of Design Procedures	56	7	39	6	15	8	18	1	2	130	24
Nothing	0	0	0	0	2	0	0	0	0	2	0
Other	2	1	3	0	1	1	3	0	0	9	2
Economic Recommendation											
Financial Incentives	58	13	37	5	13	5	10	0	6	134	28
Nothing	4	0	1	1	2	0	0	0	0	7	1
Other	6	1	4	0	0	0	1	0	0	11	1
Institutional Recommendation											
Revised Codes + Zoning	10	2	16	1	10	5	2	0	2	40	10
Union Agreements + Skill Training	7	2	5	1	3	1	2	0	1	18	5
Third Party System or Component Qualification	6	2	5	1	3	2	0	0	3	17	7
Nothing	3	1	2	1	2	0	0	0	0	7	2
Other	2	0	0	0	0	0	1	0	0	3	0

TABLE 6 Organizations and/or Institutions Considered Best Able To Implement Recommendations as Proposed in Table 5

	Engineers		Architects		Code Officials		Homebuilders		Mobile Home	Total	
	All	Exp.	All	Exp.	All	Exp.	All	Exp.	Mfgrs.	All	Exp.
Federal Government	48	11	27	5	17	11	9	3	6	107	35
State Government	15	3	17	4	10	7	4	1	2	48	16
Local Government	10	1	11	2	11	7	7	1	1	40	11
Academic Institutions	27	5	24	2	8	4	11	2	2	72	14
Non-Profit Research Institutions	34	3	25	4	16	7	13	1	3	91	17
For Profit Research Centers	32	6	21	2	6	2	9	1	2	70	12
Private Industry	58	10	38	4	19	11	23	3	7	145	33

TABLE 7 Problems Encountered by Solar Heating and Cooling Equipment Manufacturers

Problem	Number of Times Cited
Lack of solar insolation data	9
Lack of working capital	18
Lack of an aggregated market	15
Unprotected patent position	6
Lack of trained engineers, scientists, and production personnel	4
Lack of raw materials	5
Uneven final product or raw material quality	0
Lack of customer credit	7
Other	19

QUESTIONNAIRE
SOLAR HEATING AND COOLING OF BUILDINGS
BUILDERS, ARCHITECTS, ENGINEERS, BLDG. OWNER/USERS

Name

Address

Affiliation of Respondent

QUESTIONNAIRE

SOLAR HEATING AND COOLING OF BUILDINGS

BUILDERS, ARCHITECTS, ENGINEERS, BLDG. OWNER/USERS

1. What is your profession or occupation?

_____

2. What is the principle activity of your organization or firm with regard to solar heating and cooling: (please check)

Contractor

☐ Residential construction

☐ Commercial/institutional construction

☐ HVAC

☐ Other (please explain) _____

Solar or HVAC Equipment

☐ Manufacture

☐ Marketing/sales

☐ Distribution

☐ Other (please explain) _____

Building Products

☐ Sales

☐ Manufacturing

☐ Distribution

Architecture

☐ Residential

☐ Commercial

☐ Institutional

Engineering

☐ Solar heating (and/or cooling) or HVAC equipment design

☐ Building heating and cooling system design

☐ Solar equipment research and development

/__/ Production of solar heating or cooling equipment

/__/ Quality control of solar heating or cooling equipment

/__/ Other (please explain)_____

Building Operation or Maintenance /__/

Labo: Unions /__/

Electric, Gas or Water Utilities (circle one)

/__/ Operation

/__/ Regulation

/__/ Other (please explain) _____

Building Codes

/__/ Administration

/__/ Regulation

/__/ Other (please explain)_____

Zoning and Land Planning

/__/ Administration

/__/ Regulation

/__/ Other (describe)_____

BUILDERS, ARCHITECTS, ENGINEERS, OWNER/USERS

1. If you have participated in any phase of design or construction of a solar heated and cooled building, please complete the following for each building and specify the geographic location:

ITEM		BUILDING LOCATION (A)	BUILDING LOCATION (B)	BUILDING LOCATION (C)
BUILDING CHARACTERISTICS				
Type	(single story) (multi story) (high rise)			
Function	(residential) (commercial) (institutional) (industrial)			
Total Cost	$			
Size	(sq. ft.)			
Financing	(turn-key) (construction mortgage) (sale-lease-back) (other)			
Bldg. code or zoning exemption required (describe briefly)				
SOLAR HEATING AND COOLING SYSTEM Characteristics				
Purpose:	(hot water) (swimming pool) (space heat) (air conditioning)			

ITEM	BUILDING LOCATION (A)	BUILDING LOCATION (B)	BUILDING LOCATION (C)
Collector type: (wet) (dry) (focussing) (passive) (open-wet) (other)			
Collector area: (sq. ft.)			
Collector mounting: (walls) (roof) (saw-tooth) (ground) (integral with wall or roof) (other)			
Retrofit (yes) (no)			
Cooling System - (dehumidification) (absorbtion) (heat pumps) (night-sky radiation) (conventional) (none)			
Energy conservation design: (double glass windows) (heat recovery system) (extra insulation) ("run-around" heat exchanger)			
THERMAL STORAGE			
Type: (water) (hydrated salts) (organic fluid) (passive storage) (pebble bed)			
Volume of storage: (ft^3)			
Capacity: (0 sun days)			
SYSTEM COSTS			
Additional energy conservation design ($)			
Collectors ($) (FOB/Installed)			
Thermal storage ($ installed)			
Estimated cost above conventional heating (and cooling) system ($)			

ITEM	BUILDING LOCATION (A)	BUILDING LOCATION (B)	BUILDING LOCATION (C)
Years to amortize (yrs.)			
Actual or estimated maintenance (hrs./yr.)			
PRIMARY REASON(S) FOR USE OF SOLAR HEATING AND COOLING Economic analyses (yes) (no)			
R&D prototype (yes) (no)			
Public relations (yes) (no)			
Non-availability of oil or natural gas (yes) (no)			
Federal, state, or local financial incentives			
Electric or gas utility rate structure penalty			

2. If you or your organization have not participated in any solar heating or cooling activities, please select from the list below the possible reasons and rank in order of importance:

- ☐ No apparent client or market interest,
- ☐ Local codes and zoning practices,
- ☐ Not economically feasible,
- ☐ Lack of data on performance and reliability of solar equipment,
- ☐ Lack of technical competence and/or design procedures,
- ☐ High degree of risk,
- ☐ Other (explain)_____

3. What types of problems have you encountered in the design, construction, or operation of solar heated and cooled buildings:

Design

- ☐ Lack of design procedures,
- ☐ Lack of solar equipment suppliers,
- ☐ Lack of specific cost and design data,
- ☐ Lack of information on similar applications,
- ☐ Codes and zoning restraints,
- ☐ Integration of solar equipment and building architecture,
- ☐ Other (describe)_____

Construction

- ☐ Lack of skilled labor
- ☐ Labor disputes (indicate type),
- ☐ Solar collector assembly or installation problem (indicate which)
- ☐ Scheduling
- ☐ Code, health and safety problems (indicate which)

☐ Cost overrun (%)

☐ Financing

☐ Installation and checkout

☐ Other (describe)_____

Operations and Maintenance

☐ Lack of (or excessive) heating or cooling capacity,

☐ Materials degredation,

☐ Poorly designed or unreliable system components,

☐ Owner or operator misuse,

☐ Equipment failures (other than collectors),

☐ Collector failures:

- ☐ Corrosion or freezing of tubes (note which)
- ☐ Sealant failure
- ☐ Absorber coating degredation
- ☐ Cover glass (or plastic) degredation
- ☐ Vandalism and acts of God
- ☐ Failures due to moisture condensation or high temperatures
- ☐ Other (describe)_____

4. Of those problems listed above which, in your opinion, must receive further attention before there can be wider use of solar heating and cooling systems: (please describe briefly for each category on the reverse of this page.)

Technical

☐ Component (collectors, thermal storage, materials, etc.)

☐ System (design, performance, reliability, etc.)

☐ Information (components, system and component design, environment, etc.

☐ Qualification (system or component)

☐ Operational (use, control, etc.)

☐ Other (describe)_____

Economic

☐ High first cost

☐ Market aggregation

☐ Incentive methods

☐ Financing methods

☐ Utility rate structure

☐ Other (describe)_____

Institutional

☐ Codes and zoning practice

☐ Labor and skill training

☐ Public acceptance

☐ Lending institution acceptance

☐ Other (describe)_____

5. What kind of actions would you (or your organization) recommend be taken to encourage the use of solar heating and cooling in buildings? If possible please state your recommendations:

Technical

Further research and development:_____

_____

_____

Development of design procedures, guidelines and data for dissemination:

_____

_____

_____

Nothing_____

Other (describe)_____

Economic

Financial incentives:_____

_____

_____

Nothing_____

Other (describe)_____

Institutional

Revised codes and zoning practices:_____

_____

_____

Union agreements and skill training:_____

_____

_____

Third party system or component qualification:_____

_____

_____

Nothing_____

Other (describe)_____

6. What organizations or institutions, in your opinion, are best able to implement the recommendations proposed in question 5.

- ☐ Federal government
- ☐ State government
- ☐ Local government
- ☐ Academic institutions
- ☐ Non-profit research institutions
- ☐ For-profit research centers
- ☐ Private industry

QUESTIONNAIRE
SOLAR HEATING AND COOLING OF BUILDINGS
SOLAR HEATING AND COOLING EQUIPMENT MANUFACTURERS

Name

Address

Affiliation of Respondent

QUESTIONNAIRE

SOLAR HEATING AND COOLING OF BUILDINGS

SOLAR HEATING AND COOLING EQUIPMENT MANUFACTURERS

1. What is your profession or occupation?

_____

2. What is the principle activity of your organization or firm with regard to solar heating and cooling: (please check)

Contractor

- ☐ Residential construction
- ☐ Commercial/institutional construction
- ☐ HVAC
- ☐ Other (please explain)_____

Solar or HVAC Equipment

- ☐ Manufacture
- ☐ Marketing/sales
- ☐ Distribution
- ☐ Other (please explain)_____

Building Products

- ☐ Sales
- ☐ Manufacturing
- ☐ Distribution

Architecture

- ☐ Residential
- ☐ Commercial
- ☐ Institutional

Engineering

- ☐ Solar heating (and/or cooling) or HVAC equipment design
- ☐ Building heating and cooling system design
- ☐ Solar equipment research and development

☐ Production of solar heating or cooling equipment

☐ Quality control of solar heating or cooling equipment

☐ Other (please explain)_____

Building Operation or Maintenance ☐

Labor Unions ☐

Electric, Gas or Water Utilities (circle one)

☐ Operation

☐ Regulation

☐ Other (please explain) _____

Building Codes

☐ Administration

☐ Regulation

☐ Other (please explain)_____

Zoning and Land Planning

☐ Administration

☐ Regulation

☐ Other (describe)_____

SOLAR HEATING AND COOLING EQUIPMENT MANUFACTURERS

1. Product Description (Give brief description of size, capacity and purpose)

Complete collector: _____

_____

Thermal storage: _____

_____

Completed solar heating and cooling systems: _____

_____

_____

Cooling units (absorbtion, heat pump, etc.) [indicate which]: _____

_____

Controls: _____

_____

Calibration instrumentation: _____

_____

Does your product have patent protection? _____

_____

Cost (FOB) _____

_____

Other (describe) _____

_____

2. Product Sales

Volume per year (estimated or actual) _____

Distribution method:

--Locally, regionally, nationwide (circle one)

--Franchised outlets, building product distributors, HVAC contractors market representatives, (circle one)

--Other _____

--Product warranty (years) _____

3. Problems Encountered

- [ ] Lack of solar insolation data,
- [ ] Lack of working capital,
- [ ] Lack of an aggregated market,
- [ ] Unprotected patent position,
- [ ] Lack of trained engineers, scientists and production personnel,
- [ ] Lack of raw materials,
- [ ] Uneven final product or raw material quality,
- [ ] Lack of customer credit,
- [ ] Other (describe)_____

4. What kind of actions in your opinion would encourage wider use of solar heating and cooling? If possible, please state your recommendations:

Technical

Funding of additional research and development projects in the following areas:_____

_____

_____

Funding of long-term test and evaluation studies to determine the following:

_____

_____

_____

Sponsorship of organization of interpendent third party qualification

_____

_____

_____

Nothing_____

Other (describe)_____

Economic

Accelerated depreciation, tax write-offs, or other forms of general incentives:

_____

_____

_____

Direct subsidy of manufacturers:_____

_____

_____

Nothing_____

Other (describe)_____

5. What organization or institution, in your opinion, is best qualified to implement the above suggestions:

- ☐ Federal government
- ☐ Local government
- ☐ State government
- ☐ Non-profit research center
- ☐ For-profit research center
- ☐ Academic institutions
- ☐ Private industry